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# Smart Sensing in Geotechnical Engineering

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**Abstract** —*Wireless sensors and wireless sensor networks have come to the forefront of the scientific community recently. The use of these sensors and the possibility of organizing them into networks have revealed many research issues and have highlighted new ways to cope with certain problems. In this paper, different uses and applications of such sensor networks in civil engineering has been surveyed. A huge number of special sensor devices has been designed and deployed to ease the process of building and monitoring structures. As the ongoing interest for this research is intense, we feel that a recording of these recent applications and trends will be useful for perceiving new applications, or relevant research problems that will prove to be helpful in further progress of this field.*

***Keywords***-*Civil Engineering; Earthquakes; Geo Tech; Slope Monitoring; Sensors;*

## I. INTRODUCTION

The advent of low-power wireless chip transceivers has enabled new possibilities for widespread instrumentation of large civil structures and distributed geotechnical systems for which large-scale testing has been limited to unique cases due to the economic burden associated with cable-based hardware [1]. However, while the number of unique wireless sensor platforms and proposed applications has continued to rapidly expand, there has been limited success in replicating previous cable-based test programs in regards to the number of deployed sensors and data rates. Consequently, a degree of skepticism and disillusion has developed over the past several years of wireless sensor network development in the context of geo-structural monitoring. Instruments, such as pore pressure transducers, geophones, accelerometers, settlement monitors, and inclinometers, are commonly used in geotechnical fieldwork. Traditionally, these instruments have been used with cable-based data acquisition (DAQ) systems that restrict their placement in urban areas and construction sites [2]. Wireless sensing systems are compatible with many geotechnical instruments and represent an improvement over tethered DAQ by eliminating concerns about maintaining of a wired connection between instruments and a global DAQ. Additionally, wireless sensors are endowed with both memory capacity and embedded data processing resources. For example, wireless sensor networks can maintain recorded data at the node so that the data can be locally processed or held until transmission is possible [3,4].Due to their durability, economical pricing, and the previously mentioned advantages, wireless sensors have potential for greatly expanded use in geotechnical engineering. With a little more research and experience, the health monitoring of buried infrastructure could be as mature an area as structural health monitoring is now. Potential applications where wireless sensors could advance the current state of geotechnical engineering practice include monitoring strain in buried pipelines and tunnels, recording vibrations near construction or blasting sites, measuring foundation settlement, and providing early warning ofslope instability.

## II. Traditional Approach

Today there are a large number of wireless applications in many engineering areas, such as communications and informatics. Wireless technology (or communication) dates back to the nineteen centuries and since then they have developed and successfully been applied to a wide range of devices and equipment used in daily life. For this reason, this technology should be considered in other areas, since many times the use of cables for testing or monitoring can bring various issues [5]. The main disadvantages of using a cable-based system are [6]:

- not all the structures can accommodate cables,
- limited physical space causes limitations on the amount of data transmitted,
- the cables may be damaged during the assembly, tests and/or transportation, and when damaged they are much more difficult to inspect to detect the problem, and possibly needing full replacement, resulting in delays. Therefore, a cable-based system requires a higher maintenance and human intervention. On the other hand, the wireless systems:
- allow an optimal placement of the sensors that normally have a small size, and diversity in usage,
- when using wireless systems, we have fewer components to relocate as the construction proceeds,
- wireless technology need low power consumption and has a limited need for surge protection,

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- plus, digital data (via wireless) has a higher reliability, and a lower likelihood of data loss when compared to analog transmissions (via cable).

Based on all this, it is clear that only benefits can come from the use of wireless technology. The use of wireless can become an important tool of current use in many areas, including civil engineering and geotechnical engineering. Therefore, they should become a routine tool in structures and infrastructures health monitoring, between others. Nowadays there is a fair number of wireless applications to geotechnics [7]. However, such applications refer to surface transmission of geodata, such as monitoring and acquisition systems [8, 9], and not to subsurface transmission of signal collected from sensor in underground testing.

## III. WIRELSS DEVELOPMENTS

Wireless sensor networks are a sub-class of wireless networks, which were developed to overcome specific problems related with wireless sensing. Wireless sensor networks may be used for many applications, but most of them share the same main requirement: to reliably measure the required variables, without interfering with the sensing environment, and requiring as low maintenance as possible. With this in mind, many solutions have been proposed along the way [10,11], and others are still under development, without no consensus about which solution fits best for all sensing applications. One of the most well-known technologies is Zigbee, which was specifically developed to satisfy the particular requirements of wireless sensor networks. It uses an electromagnetic carrier operating in the 2.4 GHz Industrial, Scientific and Medical (ISM) bands, where the wireless communication channel must be shared with Wi-Fi and Bluetooth, also sometimes used for data communication. Such wireless sensor networks may be of great help for geotechnical applications, when the data is gathered at the surface, or even in underground, when the transmission is done in free space. However, a few considerations must be made when attempting to use such technology for underground data collection. The development of wireless sensors technology presents a great opportunity for developing low-cost monitoring or data acquisition systems for civil structures and infrastructures.

### 3.1. Applications in Geotechnical Engineering, Monitoring and Field

There are different types of sensors available for monitoring tests and for data acquisition intended for almost any kind of structure or infrastructure, onshore or offshore [12, 13], mainly in urban excavations [14], slopes and compaction of highways, railways or earth dams [15] and bridges [16,17]. Many of the monitoring systems involve measurements of different types of sensors such as: pore water pressure cells, inclinometers, earth pressure cells and settlement meters. For example, the work of [18] presents commercially available soil moisture probes and soil tilt sensors combined with low-power, wireless data transmitters to form a self-configuring network ofsoil monitoring sensors (solar-powered). This research has shown that commercially available wireless instrumentation can be modified for use in geotechnical applications [18]. This type of monitoring is specially installed when instability can have lost of human lives or if the construction site has high seismic hazard [19,20]. Wireless sensors have brought many advantages for monitoring, such as a perfect cut-off of water, no weak point avoiding data loss due to a cable damage, influence of lightning, lower costs with placement and no cables. Furthermore, wireless ethernet data acquisition systems were also implemented in physical tests, like centrifuge tests [21]. This type of tests requires transmitting data collected in a moving, increased-acceleration environment, and the traditional methods (slip rings) have limited accuracy as well as limited number of instruments that can be used to data acquisition. This study obtained good results with the wireless technology although it concluded that it depends on the g-level, transmission direction, and type of wireless card used. Nevertheless, wireless technology is still scarce in nearly all kinds of "in situ" tests, like cone penetrometers, pressure meters, vane tests, seismic waves based tests or dynamic load plate tests, among others, use the transmission of signals by a cable with wires from the sensors installed on the probe. This implies, in the case of transmission of signals from down-hole to surface via cables, that before the test all the necessary rods and cables are gathered in the surface, assembled and the cables inserted inside the rods. This may cause some inconvenient during the test, but still these are the current tools available and the only that engineers use for soil testing. The use of a wireless system for the soil test itself is something that some have mentioned but few have tried.

## IV. CONCLUSION

WSNs with dense wireless sensors provide a potential solution for long-term, scalable SHM of bridges by providing easier installation and efficient data management at a lower cost than that of traditional tethered monitoring systems. The researchers mentioned previously have dedicated their efforts to promote the WSNs-based bridge health monitoring system with the aim of replacing wired structural monitoring systems. Many available wireless sensor systems are already quite capable and can be expected to replace the traditional wired sensor systems for bridge monitoring. However, wireless sensing technology is still in its infancy; much work remains for bringing this promising technology to fulfill the requirement of complex bridges monitoring and evaluation.

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